

WHITE POINT ADJUSTING METHOD, COLOR IMAGE PROCESSING
METHOD, WHITE POINT ADJUSTING APPARATUS AND LIQUID
CRYSTAL DISPLAY DEVICE

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BACKGROUND OF THE INVENTION

Technical Field

10 The present invention relates to a color image processing
technology for a color output device. More particularly,
the invention relates to a method and an apparatus for
adjusting a white point with higher accuracy in a liquid
crystal display device.

Prior Art

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As display devices for image displaying on a personal
computer, a television set or the like, and for various
other monitors, in addition to a CRT, liquid crystal
devices (LCD) have come into wide use in recent years.
In a color display system using the CRT, the LCD or the
like, it is considered ideal to bring colors to be
reproduced as close as possible to natural ones. It is
also required that an apparatus should make an automatic
adjustment or an operator (user) should make a manual
adjustment according to the installing state of the
apparatus using the CRT or the LCD, i.e., an environment
of illumination or the like where the apparatus is set,
in order to display an optimal color suited to each
environment. In addition, it is strongly demanded that
the capability of displaying a same color irrespective of
the kind of an output device should be provided. Among
these technologies, great importance is placed especially
on a white point adjustment designed to adjust an

When designing a color display system, a more optimal white point is decided by adjusting maximum luminance values of the points R, G and B or changing the positions of the points R, G and B in the drawing. For example, in

the color display system using the LCD, preferably, a white point should be decided by taking into consideration a spectral radiation characteristic of a backlight or a transmission characteristic of a color filter.

In the prior art, for example, there is Japanese Patent Laid-Open No. Hei 2(1990)-271389 gazette. This gazette discloses a technology to correct gray level data so as to set a liquid crystal luminance-gray level data characteristic to be linear, in order to enable full-color image displaying having excellent display quality to be performed by preventing color shifting. Another gazette of Japanese Patent Laid-Open No. Hei 2(1990)-271793 discloses a technology to adjust chromaticity by uniformly increasing luminance of a low gray level side of B (blue) or R (red)/G (green) and preventing a reduction in luminance of the entire screen, when low gray level displaying continues.

On the other hand, as one of the problems inherent in a TFT LCD monitor or the like, a phenomenon of blue shifting occurs in halftone gray (halftone achromatic color) especially at a low gray level. This phenomenon specifically refers to a case where during displaying of an achromatic color (i.e., color with R, G and B set at the same gray level) on the TFT LCD device, the color becomes bluish (i.e., the chromaticity coordinate shifts toward a blue color) as a gray level value thereof is reduced.

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crystal when the liquid crystal cuts off a light. Once
such a phenomenon occurs, the white point is greatly
shifted from its setting at the low gray level even if
the white point of the highest gray level can be adjusted
5 to a desired chromaticity coordinate (color temperature).
This phenomenon has been very conspicuous in certain
kinds of LCD panels, posing a new problem to be solved.

As shown in the drawing, because of color shifting caused
10 by a viewing angle, in connection with the foregoing
phenomenon of color shifting at the halftone gray level,
color shifting is increased from a white point spec value
of a white color at the halftone gray level. There has
been a strong demand for assurance of a high viewing
15 angle in the LCD in recent years. But a more conspicuous
occurrence of color shifting as the angle of viewing
(viewing angle) the display is inclined from the front
face has been another serious problem.

20 In the gazettes of Japanese Patent Laid-Open No. Hei
2(1990)-271389 and Patent Laid-Open No. Hei
2(1990)-271793 of the prior art, no mention is made for
the need to correct white point shifting at the halftone
gray level. Especially, in the gazette of Japanese
25 Patent Laid-Open No. Hei 2(1990)-271389, a technology is
disclosed that a luminance ratio of R, G and B is
maintained constant at all the gray levels. But this
maintenance technology of the constant luminance ratio is
completely different from maintenance technology of a
30 constant white point at all the gray levels in the case
of the LCD.

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signal in a direction of converging a white point at a
halftone gray level for each color temperature set in the
first step; and a third step of adjusting chromaticity on
a screen of the liquid crystal module by adding the
5 offset quantity decided in the first step and the offset
quantity set in the second step to the input video signal
(third step).

10 In this case, the input video signal is composed of R, G
and B color signals, and for the white point setting in
the first step, a prescribed color temperature is set as
a default value. If a color temperature is set to a high
temperature side with respect to the prescribed color
15 temperature, luminance of R (red) and G (green) color
signals is reduced. Thus, by using a color temperature
of a low side as a reference, luminance of B (blue) can
be increased in relative fashion even in an LCD having
luminance which cannot be increased exceeding highest
luminance. As a result, even at a high color
20 temperature, an adjustment can be made in such a manner
as to set a white point of a highest gray level on a
coordinate of each color temperature on a CIE
chromaticity coordinate. To set a color temperature of a
low side by using a high temperature side as a reference,
25 it is only necessary to make an adjustment in such a
manner as to reduce luminance of B (blue).

30 The adjusting method may further comprise another step of
adjusting luminance of the entire input video signal
after the white point is set in the first step. This
step is preferable, because luminance (spec value of

highest luminance) can be maintained substantially constant even if color temperature setting is changed. A specific example may be providing an inverter circuit, which sets a spec value of luminance in a color temperature side having a largest offset quantity (a minus value) while a backlight still has room, and adjusts highest luminance according to an offset quantity following color temperature setting.

5 The offset quantity set in the second step may be calculated with accuracy of bits larger in number than those of the input video signal. Accordingly, replacement can be made by selecting an appropriate gray level for realizing desired luminance from higher-density gray levels, and highly accurate convergence of a white point can be realized by a simple constitution. The calculation with accuracy of bits larger in number than those of the input video signal enables gray level coordinates arrayed at equal intervals to be transformed into ones arrayed at unequal intervals corresponding to desired luminance different from luminance of the gray levels. Therefore, convergence of a white point can be realized.

25 The present invention provides a color image processing method for supplying an entered video gray level signal to a display panel adapted to output a color image. This color image processing method comprises the steps of: setting an achromatic color of a particular gray level at a specified color temperature on the basis of a set transformation quantity; setting an adjusting value for

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number of bits after calculation, in other words,
adjusted with high accuracy. As a result, highly
accurate convergence of a white point can be realized.

5 The present invention provides a liquid crystal display
device. This liquid crystal display device comprises: a
driver for driving a liquid crystal cell on the basis of
each of adjusted R, G and B color signals, and executing
a contrast adjustment for the liquid crystal cell
10 according to user setting; setting means provided in a
stage before the driver to set a white point of a
particular gray level in accordance with a hue of a
prescribed white color; and adjusting means provided
independently of the driver to substantially maintain a
15 hue of a white color set by the setting means for gray
scales other than the particular gray level.

The adjusting means may maintain the hue of a white color
for each gray level irrespective of a contrast adjustment
executed by the driver. In this case, for example, if γ
20 characteristic can be set by an X driver (source driver)
for driving the liquid crystal cell, the set white point
adjustment can be maintained irrespective of a change in
the γ characteristic.

25 The adjusting means may be capable of adjusting the
distribution of luminance among the R, G and B color
signals by adding an offset quantity into original γ
characteristic of the entered R, G and B color signals,
30 and outputting the result to the driver. Accordingly,
different from the general case of, for example a driver

adjustment such as a contrast adjustment which is commonly set simultaneously among R, G and B, white point convergence can be realized in a direction of setting white points constant at all gray levels by changing a luminance ratio among R, G and B.

Furthermore, the adjusting means may change an offset quantity on the basis of a reference voltage applied following the contrast adjustment of the driver. In this case, a white point can be set constant for each gray level while the adjusted contrast adjustment is maintained. For example, if the liquid crystal device is constituted to have a reference table for each adjusted contrast (γ characteristic), then white point convergence can be realized irrespective of contrast setting of the liquid crystal cell.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Fig. 1 is a view illustrating an entire constitution of a liquid crystal display device according to an embodiment of the invention.

Fig. 2 is a functional block diagram illustrating features of the embodiment.

Fig. 3 is a view illustrating a content of a first table 46 stored in a memory 22.

Fig. 4 is a view illustrating a content of a second table 47 stored in the memory 22.

5 Figs. 5(a) and 5(b) are views illustrating a method of adjusting γ (Gamma) characteristic based on transformation of gray level intervals according to the embodiment.

10 Fig. 6 is a view showing an example of a result of adding a white point adjustment according to the embodiment.

Fig. 7 is a view showing an example of adding a white point adjustment according to the embodiment.

15 Fig. 8 is a typical CIE_{xy} chromaticity diagram illustrating the invention.

Fig. 9 is a view illustrating a change in color temperature for each gray level in an LCD.

20 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS
OF THE INVENTION

Next, detailed description will be made for the present invention on the basis of the preferred embodiments shown in the accompanying drawings.

25 Fig. 1 is a view illustrating an entire constitution of a liquid crystal display device according to an embodiment of the present invention. A reference numeral 10 denotes a liquid crystal monitor (LCD monitor) as a liquid crystal display panel, which includes a liquid crystal module 30 having, for instance a thin-film transistor (TFT) structure, and an interface (I/F) board 20

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Fig. 2 is a functional block diagram illustrating features of the embodiment. The ASIC 21 includes a white point adjusting unit 40, and color emulation (pseudo color expansion) 48. R/G/B data received by 8 bits from the PC or WS system is adjusted by a highest gray level adjusting unit 41 and each gray level adjusting unit 42 in accordance with a set color temperature and a gray level of each color that has been entered. In this case, the highest gray level adjusting unit 41 and each gray level adjusting unit 42 respectively make adjustments by adding in prescribed offset quantities while referring to first and second tables 46 and 47 provided in the memory

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out on the basis of the table shown in Fig. 3, a problem
of a reduction in luminance occurs with a color
temperature increase unless any considerations are given
in this regard. In other words, as a result of
5 increasing blue luminance in relative fashion by reducing
red and green luminance, with high color temperature
setting, a luminance spec value cannot be satisfied at
5500K as a reference. To solve this problem, according
to the embodiment, the inverter control circuit 43 shown
10 in Fig. 2 performs inverter control while the backlight
has room, and output its result to the inverter circuit
49. In other words, in the case of the table shown in
Fig. 3, a luminance spec value is defined by a high color
temperature side (9500K), and when a low color
15 temperature is set, the luminance spec value is
maintained by automatically switching an inverter output
such that a reduction is made to highest luminance at the
time of high color temperature setting. Thus, a spec
value of highest luminance can be prevented from being
20 changed even if a change occurs in color temperature
setting. Specifically, when setting a white point (color
temperature), panel luminance is changed at high and low
temperature settings unless any considerations are given
in this regard. According to the embodiment, however, by
25 switching an inverter output depending on each set color
temperature, a change of highest luminance can be limited
to a minimum.

Instead of the table shown in Fig. 3, as described above,
30 if a reference table is prepared in such a manner as to
reduce blue luminance when setting a white point of a low

temperature side by using 9500K of a high temperature side as a reference, inverter control to be performed is opposite to the foregoing, and a similar effect can be obtained by defining a luminance spec value with a low color temperature side (5500K) and reducing highest luminance at the time of high color temperature setting.

Next, description will be made for an adjustment of an offset quantity at a prescribed color temperature, which is performed in each gray level adjusting unit 42.

Fig. 4 shows a content of the second table 47 stored in the memory 22. This table is used to decide an offset quantity for each color temperature set by the highest gray level adjusting unit 41 based on the first table in such a way as to maintain a white point substantially constant (converged) at all the gray levels. In other words, even if a chromaticity coordinate of each color temperature is set at a highest gray level as described above, a white point can be converged by paying attention to the problem of shifting from the set coordinate at other gray levels and then deciding offset quantities of red, green and blue at each gray level in accordance with a characteristic of the LCD to be used. In Fig. 4, values rr1 to rr9, gg1 to gg9 and bb1 to bb9 are offset quantities provided with accuracy of 8 bits or more (e.g., accuracy of 10 bits) when input RGB data is 8 bits, and 9 points are extracted from 256 gray levels including a lowest gray level. But, the number of points to be extracted can be optionally decided.

Detailed description will now be made for an adjustment of an offset quantity at a specified color temperature using the table shown in Fig. 4, by taking an example of an 8 bit color gray level as input video data.

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Figs. 5(a) and 5(b) are views illustrating a method of adjusting γ (Gamma) characteristic on the basis of transformation of gray level intervals according to the embodiment. In the case of the LCD, 0 to 255 gray levels of R/G/B (in the case of 8 bits) correspond to liquid crystal driving voltages (not shown) by one to one through a D/A converter (DAC) (not shown) in the liquid crystal cell control circuit 31 of the liquid crystal module 30. Luminance of each color at a corresponding level is realized on the LCD by means of a liquid crystal driving voltage, and chromaticity of a mixed color (e.g., white) on the CIE chromaticity coordinate is decided on the basis of distribution of luminance among the respective colors. It should be noted, however, that a reference voltage of a driver for each of R, G and B of the liquid crystal module 30 is set in common among R, G and B.

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Generally, in order to maintain a white point defined at the highest gray level of a white color for a white color of other gray levels, distribution of luminance among R, G and B must be adjusted at each gray level in accordance with a characteristic of an LCD to be used. This means that γ characteristic of each color of R, G and B must be changed independently. However, since reference voltage

setting of the driver (source driver 35) on the liquid crystal module 30 is usually carried out in common among R, G and B, this operation (independent setting for each color) is not permitted in the driver side. Thus, γ characteristic must be adjusted independently for each of R, G and B in a previous stage, and passed to the driver of the liquid crystal module 30. Herein, γ curve representing a relation between a gray level of each color and corresponding luminance becomes one like that shown in Fig. 5(a). In the drawing, the axis of abscissa indicates gray levels arrayed at equal intervals, and the axis of ordinate indicates luminance. Changing of luminance corresponding to each gray level of the axis of abscissa means an adjustment of the γ curve. However, as described above, setting of a reference voltage cannot be changed independently for each color on the liquid crystal module 30 side. Consequently, γ characteristic cannot be changed for each color.

Therefore, according to the embodiment in, γ curve for each color, gray level coordinates arrayed at equal intervals are transformed into gray level coordinates at unequal intervals in order to set coordinates to desired luminance different from corresponding luminance. In other words, as shown in Figs. 5(a) and 5(b), a gray level for realizing desired luminance is selected from higher-density gray levels (for example, 10 bits, 1024 gray levels) existing among the gray level coordinates (e.g., 256 (in the case of 8 bits)) arrayed at equal intervals, and an original gray level is replaced by this selected gray level. For example, in Fig. 5(a), assuming

that luminance corresponding to n gray level is L , the n gray level is replaced by n' gray level which is multilevel if L' is desired for a luminance adjustment.

Similarly, in accordance with desired luminance, $n+1$ is replaced by $n+1'$, $n+2$ by $n+2'$, and so on, thereafter. A quantity of such replacement is decided on the basis of the offset quantity shown in the second table of Fig. 4.

Fig. 5(a) illustrates transformation of gray level intervals. It can be understood that the multilevel

transformation of the embodiment enables the gray level coordinates arrayed at equal intervals to be transformed into ones at unequal intervals corresponding to desired luminance different from the corresponding luminance thereof. According to the embodiment, apparently, by

means of calculation with accuracy of bits larger in number than those of the input video data, an adjustment of γ characteristic curve can be carried out easily and highly accurately.

According to the embodiment, to adjust a white point for each gray level, as it is impractical to execute an adjustment at all of the 256 gray levels, 9 gray levels including highest and lowest gray levels arrayed at equal intervals are adjusted to be transformed into ones at unequal intervals, and interpolation is carried out between the 9 gray level. Any kind of interpolating method can be used, and an almost satisfactory result can be obtained by linear two-point interpolation.

With the embodiment, an adjustment is carried out with

accuracy of 10 bits in the case of 8 bit color gray level
and, when data is passed to the driver of the 8 bit
liquid crystal module 30, 10 bit equivalence is set in
the color emulation 48 described above with reference to
5 Fig. 2. In the color emulation 48, 10 bit equivalence is
realized by, for example dither or FRC (frame control).

As apparent from the foregoing, according to the
embodiment, separately from and independently of a
10 contrast adjustment by the liquid crystal module 30 from
the user I/F 11, an white point adjustment can be carried
out by providing adjusted γ characteristic to the
original γ characteristic in the previous stage. As a
result, different from the conventional case where all of
15 the previous settings become unusable when a change
occurs in γ curve, it is possible to execute a desired
white point adjustment in accordance with a contrast
adjustment of a latter stage. Moreover, by adjusting γ
characteristic of each color independently of the liquid
20 crystal module 30, it is possible to dynamically provide
unique γ characteristics to a plurality of applications
in one screen, such as usual PC applications, moving
picture applications window-displayed therein or the
like.

25 Each of Figs. 6 and 7 shows an example of a result of
adding a white point adjustment according to the
embodiment. Specifically, Fig. 6 shows a result of each
color temperature setting from 5500K to 9500K in the
30 highest gray level adjusting unit 41 on a CIE

chromaticity coordinate, and a result of adding an
adjustment for maintenance of a constant white point at
color temperatures 5500K and 9500K in each gray level
adjusting unit 42. As apparent from comparison of Fig. 6
5 with no adjustment addition described above with
reference to Fig. 9, it can be understood that with the
embodiment, a white point is realized along a black body
locus at each color temperature as a set. It can also be
understood that at color temperatures 5500K and 9500K, a
10 white point is converged without any great changes even
if a gray level is different.

Fig. 7 shows shifting of a white point caused by viewing
angle shifting, which results from the addition of a
15 white point adjustment of the embodiment. From
comparison of Fig. 7 with no adjustment addition of Fig.
9, it can be understood that changes are reduced in both
of a solid-line arrow A and a broken-line arrow B, the
arrow A indicating a moving direction of a white point at
20 each gray level when a viewing angle is increased in a
horizontal direction, and the arrow B indicating a moving
direction of each gray level when a viewing angle is
increased, and white point shifting caused by the viewing
angle is reduced.

25 Therefore, with the embodiment, a white point adjustment
can be executed for each of R, G and B independently of
one another and optionally in the previous stage for the
source driver (X driver) 35 usually setting γ
30 characteristic of the liquid crystal module 30

According to the embodiment, if γ adjustment is made by the source driver 35 of the liquid crystal module 30, a second table 47 can be provided for each adjusted γ characteristic (each contrast). As a result, it is possible to maintain a white point substantially constant (converged) for each gray level by changing an offset quantity irrespective of panel contrast setting.

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